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RAPID DECOMPOSITION OF PERMETHRIN IN THE OUTER FLY OF AN EXPERIMENTAL TENT IN PAKISTAN

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ABSTRACT. The residual activity of permethrin on the canvas of an experimental tent, used by nomadic refugees in a malarious area in northern Pakistan, was assessed. A permethrin emulsion sprayed on the inner sheet of a pitched double-fly tent (0.5 g/m²) had an effective residue for at least 6 months in bioassays using the local malaria vectors, *Anopheles stephensi* and *Anopheles culicifacies*. However, a high concentration of permethrin (2 g/m²) sprayed on the inner surface of the outer tent, simulating single-fly tents, decomposed within 2 months. These findings were confirmed with chromatographic analysis. Under the conditions found in the study area, the shortened residual effect most likely resulted from photodecomposition, not previously reported to affect operational performance of this insecticide.

INTRODUCTION

Tents are extensively used by nomads, displaced people, and victims of natural and man-made disasters throughout the world, These populations are often at risk of contracting malaria and other vector-borne diseases. In the past, malaria control has been severely hampered by nomadic movement, e.g., during the 1950s and 1960s when malaria eradication was attempted (Motabar and Behbahni 1973). The efficacy of treating tents with DDT, dieldrin, and HCH in Iran during this era was limited by the short residual activity of these insecticides. Even the residue of DDT formulated as a wettable powder, with a long residual effect indoors, was quickly lost when applied to tents (Motabar 1974). The new pyrethroids, such as permethrin, have a long residual effect and have a good "grip" on textiles, such as bednets, curtains, and clothes (Rozendaal 1989, Curtis et al. 1991). These characteristics appear ideal for use on tents. Permethrin, with its very low human toxicity, can be applied to inhabited tents without risk of contaminating the inhabitant or contents of the tent. Recently, procedures for permethrin application to pitched tents were developed (Qureshi et al. 1990), and in stored conditions, permethrin-treated tents showed no loss of residual activity after 1 year (L. L. Sholdt, unpublished data).

In 1990 a field trial was implemented, and 5,600 tents of 26,000 nomadic Afghan refugees in the North West Frontier Province (NWFP) of Pakistan were sprayed with a permethrin emulsion in an attempt to combat serious seasonal outbreaks of malaria. Prevalence surveys showed that the nomadic populations that had received the permethrin spray were affected significantly less than the local population in the same year and had less malaria in comparison with the previous year without a permethrin spray (Bouma et al. 1996).

This paper presents the results of the residual effect of permethrin in a tent pitched in the trial area. This double-fly tent was of the type most commonly used by the nomadic refugees in the area. The residual effect of permethrin sprayed on single-fly tents, used by less than 5% of the nomads in the trial area, was also assessed.

MATERIALS AND METHODS

Study area and siting of experimental tent: The study was conducted in South Waziristan Agency, a tribal area in the NWFP of Pakistan, at 33°N latitude, bordering Afghanistan. The study area was situated close to the town of Wana, on a plain at 1,400 m, part of the southern mountain ridges of the Hindu Kush. The area has a dry climate (rainfall 25–50 cm per year). Mean monthly temperatures during the period of study decreased from 27.7°C in June to 7.4°C in December. The experimental tent was pitched approximately 200 m from the nearest sprayed refugee tents in the trial area in South Waziristan, in similar (unshaded) conditions. A guard of the local Basic Health Unit of the Afghan refugee health program supervised the experimental tent to prevent theft and assure that the position of the tent remained unchanged during the 6 months of the study.

Tent, permethrin, and method of spraying: Tents provided to the Afghan refugees in Pakistan by the United Nations High Commission for Refugees (UNHCR) consisted of an outer tent

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(canvas, 100% cotton, 48/50 and 26/28 threads per inch warp and weft, respectively), plain weave, basic weight in loom state 480 g/m^2. The outer tent was lined with a thin cotton "dossotti". The inner tent was made of 2 thin sheets of cotton, plain weave, each weighing 195 g/m^2. The experimental tent used in this study was provided by UNHCR. The tent had been used by refugees from 1982 until 1989. It seemed likely that little of the original waterproofing (paraffin wax and aluminum acetate) of the outer tent remained. The design of the experimental tent was modified slightly for the study in that the thin "dosotti", the lining of the outer fly, was removed to resemble a single-fly tent.

Permethrin (25% w/v emulsifiable concentrate [EC], cis/trans ratio 40/60) was procured by UNHCR from Imperial Chemical Industries (ICI), Pakistan. The spray strategy followed the recommendations developed for U.S./Pakistani army tents (Qureshi et al. 1990). Permethrin EC 25% (152 ml) and water (7.56 liters) were mixed to obtain an emulsion of 0.5% and applied from the inside with a Hudson hand-pump compression sprayer to the point of run-off, aiming to obtain a permethrin concentration of approximately 0.5 g/m^2. The outer tent was sprayed from the inside, after temporary removal of the inner tent, simulating the spraying of a single-fly tent. The volume of water needed for absorption of the canvas of the inner and outer tent was only measured after the study. Each layer of the inner tent had the capacity to absorb approximately 210 ml/m^2 and the outer tent, 420 ml/m^2. Because the inner tent consisted of 2 identical adjoining layers, the spraying of one layer and the redistribution of the emulsion from the sprayed to the adjoining layer resulted in the desired concentration. However, based on the absorption of the heavier outer tent, a concentration of approximately 2 g/m^2 could have been anticipated.

Measuring residual activity and chemical analysis: Assays were carried out on samples of fabric (12 × 12 cm) cut from the tent wall facing west. Repairs were made with inserts of untreated cotton of the same material. Control samples from the inner and outer tents were obtained before the experimental tent was sprayed. The first samples were taken 1 day after application of permethrin (June 25, 1990), followed by monthly intervals for the bioassays and 2 monthly intervals for the chromatography. Samples were refrigerated (4°C) when stored and were transported by express mail in separate aluminum foil/glass containers.

Gas–liquid chromatography was carried out by Wellcome Environmental Health UK. The amounts of remaining (pure) permethrin cis and trans isomers were determined. Delay between sampling and chromatographic analysis was approximately 2–3 wk.

Bioassays were carried out by the National Institute for Malaria Research and Training in Lahore, Pakistan. Delay between sampling and exposure was approximately 1 wk. For the assays, 3–5-day-old (female) bloodfed vector specimens were used. Both mosquito vector species prevalent in the area were exposed. Strains of *Anopheles culicifacies* Giles and *Anopheles stephensi* Liston were used from laboratory stock (the latter resistant to DDT and malathion), and both were fully susceptible to permethrin. Mosquitoes were exposed, in batches of 5 specimens, for 15 min to the sprayed side of the canvas (marked by the field workers) under shallow Petri dish halves, following a published method (Qureshi et al. 1990). The test on each fabric sample was repeated 4 times, corresponding with a total of 20 specimens exposed per species for each test. The temperature during tests was approximately 23°C. Exposed specimens and controls were held, and mortality (dead mosquitoes divided by the total number of exposed mosquitoes × 100%), corrected for control mortality using Abbott's formula, was assessed after 24 h. Every month, prior to testing, full susceptibility of both vector species to permethrin (0.25% impregnated papers, provided by the World Health Organization [W.H.O.]) was reconfirmed following the W.H.O. standard procedure for susceptibility testing (W.H.O. 1990).

RESULTS

Gas-chromatography: Permethrin concentrations from the tent samples removed the day after the spraying showed 474 mg/m^2 in the inner tent and 1,967 mg m^2 in the outer tent, which correspond with calculated levels using the absorption rates of both fabrics. Analysis of the samples from the inner tent showed a decline to 275 mg/m^2 after 6 months (Fig. 1). The slight increase in the 2nd sample (August) was probably due to an uneven redistribution of permethrin in the 2 inner tent layers.

In the outer tent, a rapid decrease of the permethrin residue was observed (Fig. 1). After 2 months, the value decreased from 1,967 mg/m^2 to 118 mg/m^2, and after 6 months, only 24 mg/m^2 remained. This corresponds with a more or less linear decline between June and December on the logarithmic scale depicted. No marked change in isomer ratio was found in samples of the inner and outer tents between June and December (data not shown). No permethrin was detected by chromatography in the control samples.

Bioassays: The bioassays showed results similar to those of chromatography (Fig. 2). Mor-

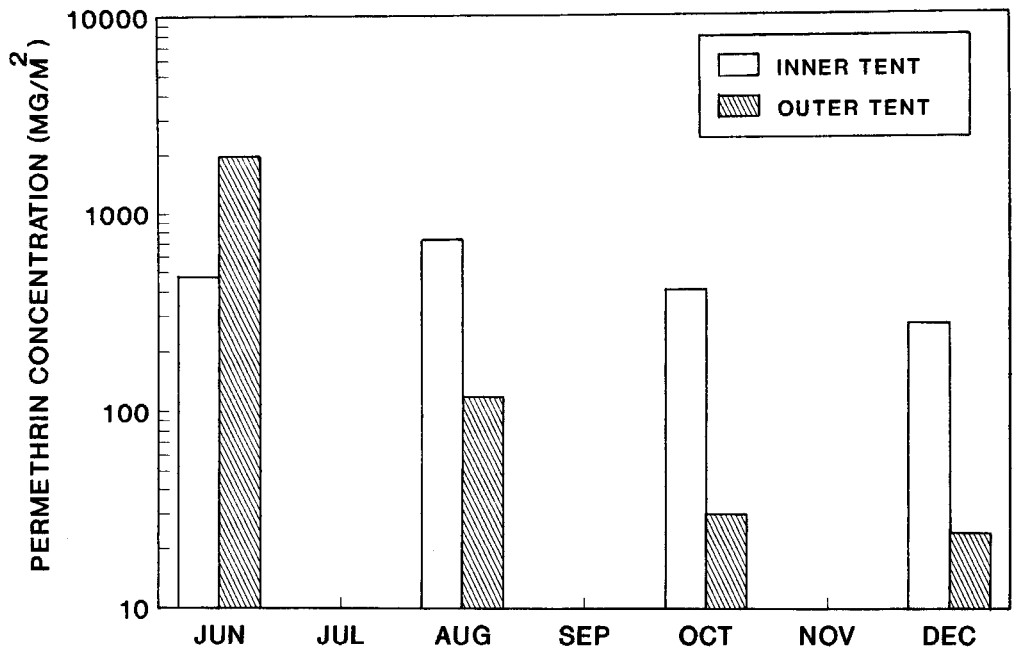

Fig. 1. Permethrin concentration (mg/m²) in samples from the inner tent (open bars) and outer tent (hatched bars) between June and December.

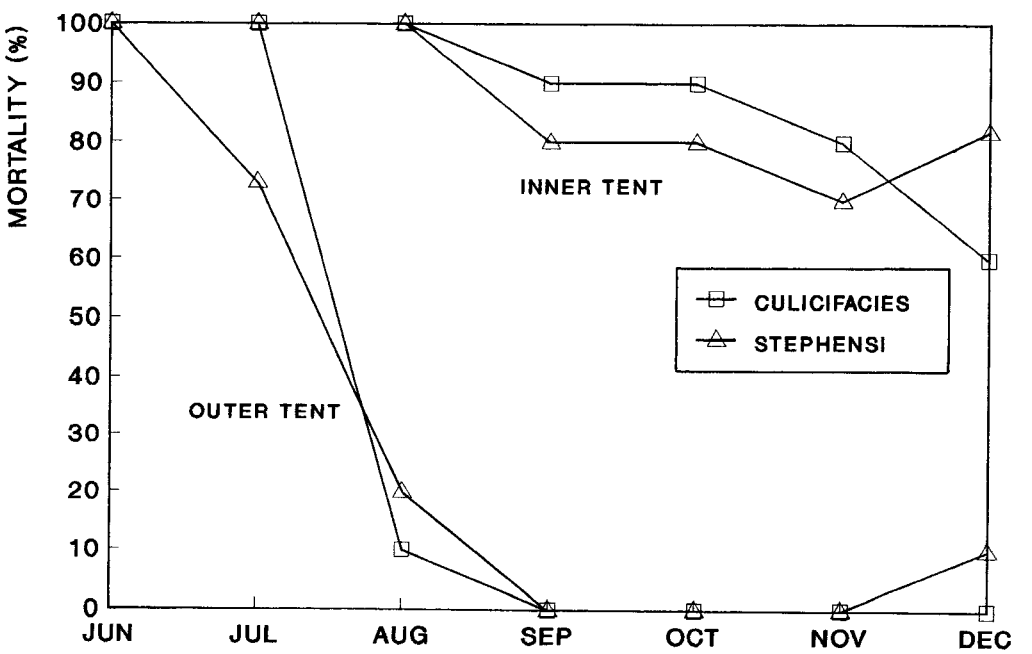

Fig. 2. Mortality in contact bioassays for *Anopheles culicifacies* (□) and *An. stephensi* (△) exposed to samples of permethrin-sprayed inner and outer tents between June and December.

tality in the bioassays conducted on the sprayed surface of the inner tent showed a gradual decrease of activity after August. Mortality 6 months after spraying was still 60% for *An. culicifacies* and 80% for *An. stephensi.* Despite the much higher initial permethrin deposit on the outer tent, mortality dropped to 20% for *An. stephensi* and 10% for *An. culicifacies* only 2 months after the spraying.

DISCUSSION

Chromatography and bioassays showed a marked difference in the longevity of permethrin sprayed on cotton material of the inner and outer tents in South Waziristan Agency in Pakistan. The residual effect of permethrin sprayed on the inner tent was sufficient to kill 60 and 80% of 2 vector species after 6 months. This effect was similar to results found in other studies in which permethrin was used on canvas of tents (Schreck 1991). However, the permethrin sprayed on the inner side of the outer tent (simulating single-fly tents) lost its activity rapidly. From the decrease during the initial 2 months, the half-life can be estimated at approximately 2 wk. Had permethrin been applied at the same concentration as that of the inner tent (0.5 g/m^2), the residual effect would have lost its efficacy in a matter of weeks. This is much shorter than was expected and would have resulted in operational failure if the tents in the trial area had been of the single-fly type.

Weathering of permethrin in textile fabrics has been reported. In an artificial weathering device to simulate tropical forested conditions, the permethrin residue (chromatography) and "knock-down effect" on *Aedes aegypti* (Linn.) were rapidly lost, although the repellency effect, vital for protective clothing, the efficacy of which was assessed in the experiments, remained measurable for a much longer period (Gupta et al. 1989, 1990). In the weathering device used, the fabric was exposed to both alternate light (xenon light source) and dark periods and sprays of water. The effect of each environmental factor separately was not assessed. Improved light stability was one of the major improvements of the 2nd and 3rd generations of synthetic pyrethroids, as compared with natural pyrethrins and the first generation of synthetic compounds (Elliot et al. 1973). Direct sunlight has been mentioned as a cause of chemical degradation (Rozendaal 1989). Under laboratory conditions, light has been shown to affect the longevity of permethrin (Barlow et al. 1977) and the decomposition of deltamethrin could be reduced 4-fold by using ultraviolet absorbers. Operational failure as a result of the photosensitivity has not been reported (Worthing 1983). Because rainfall, which may account for some weathering, is very low in the study area of South Waziristan, the photosensitivity of permethrin is the most likely factor to have affected the residual life of permethrin. Sunlight at high altitude has a high content of ultraviolet light. Because the trial area was situated at 1,400 m, high-altitude sunlight may have contributed to the rapid decomposition of permethrin. However, follow-up investigations in a lowland area in NWFP showed a similar shortened residual activity in single-fly tents (M. Rowland, unpublished data).

The use of permethrin in double-fly tents may play an important role in the prevention of malaria (Bouma et al. 1996) and other vector-borne diseases in nomadic and refugee populations. More light stable formulations of pyrethoids are required when vector control in single-fly tents is attempted. Therefore, the decomposition of permethrin, and other light stable pyrethroids such as deltamethrin and lambdacyalothin, in single-sheet tents deserves further study under controlled climatic conditions, with sufficient replicate tests for statistical analysis.

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REFERENCES CITED

Barlow, F., A. B. Hadaway, L. S. Flower, J. E. H. Grose and C. R. Turner. 1977. Some laboratory investigations relevant to the possible use of new pyrethroids in control of mosquitoes and tsetse flies. Pestic. Sci. 8:291–300.

Bouma, M. J., S. D. Parvez, R. Nesbit and L. Winkler. 1996. Malaria control with permethrin applied to tents of nomadic Afghan refugees in northern Pakistan. Bull. W.H.O. 74(3).

Curtis, C. F., J. D. Lines, P. Carnevale, V. Robert, C. Boudin, J. M. Halna, L. Pazart, P. Gazin, A. Richard, J. Mouchet, J. D. Charlwood, P. M. Graves, M. I. Hossain, T. Kurihara, K. Ichimori, Li Zuzi, Lu Baolin, G. Majori, G. Sabatinelli, M. Coluzzi, K. J. Njunwa, T. J. Wilkes, R. W. Snow and S. W. Lidsay. 1991. Impregnated bed nets and curtains against

malaria mosquitoes, pp. 5–46. *In:* C. F. Curtis (ed.). Control of disease vectors in the community. Wolfe Publ. Ltd, London.

Elliot, M., A. W. Farnham, N. F. Janes, P. W. Needham, D. A. Pulman and J. H. Stevenson. 1973. A photostable pyrethroid. Nature (London) 246:169–170.

Gupta, R. K., L. C. Rutledge, W. G. Reifenrath, G. A. Gutierrez and D. W. Korte. 1989. Effects of weathering on fabrics treated with permethrin for protection against mosquitoes. J. Am. Mosq. Control Assoc. 5:176–179.

Gupta, R. K., L. C. Rutledge, W. G. Reifenrath, G. A. Gutierrez and D. W. Korte. 1990. Resistance of permethrin to weathering in fabrics treated for protection against mosquitoes (Diptera: Culicidae). J. Med. Entomol. 27:494–500.

Motabar, M. 1974. Malaria and nomadic tribes of southern Iran. Cah. O.R.S.T.O.M. Ser. Entomol. Med. Parasitol. 12:175–178.

Motabar, M. and G. R. Behbahni. 1973. Nomadism and the problem of malaria eradication in southern Iran. W.H.O./Mal/73.813.

Qureshi A. A., M. Iqbal, C. E. Schreck, L. L. Sholdt, R. W. Smertz, A. Khan, R. Mohy-ud-Din, I. A. Malik and L. J. Legters. 1990. Personal protective programme for the Pakistan Armed Forces. Pak. Armed Forces Med. J. 43:30–37.

Rozendaal, J. A. 1989. Impregnated mosquito nets and curtains for self-protection and vector control. Trop. Dis. Bull. 86:R1–R41.

Schreck, C. E. 1991. Permethrin and dimethyl phthalate as tent fabric treatments against *Aedes aegypti.* J. Am. Mosq. Control Assoc. 7:533–535.

World Health Organization. 1990. Report of the Expert Committee on Insecticides. W.H.O. Tech. Rep. Ser. 585.

Worthing, C. R. (editor). 1983. Pesticide manual, 7th ed. British Crop Protection Council, London.